

## Comparison Between Serum Insulin Levels and Its Resistance With Biochemical, Clinical and Anthropometric Parameters in South Indian Children and Adolescents

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**Abstract** There is a rising trend in the prevalence of insulin resistance among obese, overweight children and adolescents. The serum insulin and its correlation with biochemical, clinical and anthropometric parameters were evaluated in 185 children and adolescents (59 control, 52 obese, 49 overweight, 25 congenital heart disease) of age group 10–17 years. The levels of serum insulin were measured by ELISA. Serum insulin levels were found to be significantly increased in children who were obese, overweight and had congenital heart disease, than controls. Serum insulin levels positively correlated with BMI, WHR, and serum C-peptide, serum leptin, total cholesterol, triglycerides, LDL-cholesterol, systolic and diastolic blood pressure. Fasting glucose levels were found to be negatively correlated with serum insulin levels. HDL-cholesterol levels were non-significant among the study groups. We identified nine obese children (five girls and four boys) with the features of metabolic syndrome and 69% of obese and overweight children were identified with insulin resistance. Insulin resistance was strongly associated with metabolic syndrome and its components, especially with central obesity and hypertriglyceridemia.

**Keywords** Serum insulin · Insulin resistance · Metabolic syndrome · Leptin · C-peptide

### Introduction

The prevalence of insulin resistance, obesity, dyslipidemia among children and adolescents is increasing rapidly in India, and it is well established that obesity is a risk factor for metabolic syndrome, type 2 diabetes mellitus and atherosclerotic coronary heart diseases in adults and as well as in children [1–3]. Multiple lines of evidence suggest that atherosclerotic changes start pathologically in coronary arteries during childhood [4]. Measurement of insulin resistance predicts future type 2 diabetes and cardiovascular diseases in children and adolescents even in the absence of hyperglycemia and diabetes [5, 6]. Insulin is a pancreatic hormone produced in the islets of langerhans with a molecular weight of 5808 Da and it is composed of 51 amino acid residues. Fasting insulin levels determine the insulin resistance [7]. Insulin resistance is a reduced physiological response of the peripheral tissues to the actions of insulin [8]. It is important to identify the individuals who are at risk of insulin resistance for primary prevention. Features of insulin resistance syndrome (or) metabolic syndrome are obesity, insulin resistance, dyslipidemia (mainly increased TG and decreased HDL), impaired glucose tolerance and hypertension [9]. It is obvious that the severity of metabolic syndrome depends on the number of risk factors involved and obesity plays a crucial role in insulin resistance syndrome [10]. However, the potential relationship between serum insulin, biochemical and anthropometric parameters has not been extensively reported in earlier studies especially in obese, overweight and congenital heart disease children and

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adolescents in South Indian population and their risk of insulin resistance syndrome. Most of the studies have given importance to adults and limited studies are available in children. The role of certain biochemical parameters in lipid metabolism is still unclear in humans [11].

The purpose of this study is to understand the association between serum insulin and biochemical, anthropometric parameters in obese, overweight and in children with congenital heart disease of South Indian population and their risk of insulin resistance. It is better to identify children who are at risk of insulin resistance at an early stage to prevent future development of metabolic syndrome, type 2 diabetes and coronary heart disease.

## Materials and Methods

The study group consists of 185 school going children within the age group of 10–17 years from different schools in Chennai. Children with congenital heart diseases from International Centre for Cardio-Thoracic and Vascular Diseases were enrolled as study participants. Informed written consent from the parents and children were obtained before the start of the study. A detailed questionnaire regarding medical history of the parents and children were recorded. This study was approved by Institutional Ethics Committee. Overweight and obese children and also children with congenital heart disease were included. Children with secondary causes of obesity, insulin dependent diabetes mellitus, and insulin independent diabetes mellitus and children with relevant drug treatment were excluded. Anthropometric measurements such as height, weight, body mass index (BMI), and waist to hip ratio (WHR) were recorded. Weight was measured using a beam balance to the nearest 0.1 kg and height was measured to the nearest centimeter using a tape stuck to the wall. Abdominal girth was measured at the level of umbilicus with the subject relaxed and in a standing posture. Hip girth was measured at the widest point of the hips at the level of the greater tronchanter with the patient standing with both feet together. Waist to hip ratio was calculated from these measurements. Children with >85th percentile for age and gender, children with >95th percentile for age and gender, were considered as overweight and obese by using Centers for Disease Control and Prevention Growth Charts. Blood pressure levels were also recorded for all children using the Mercury Sphygmomanometer.

Venous blood samples were collected after 12 h fasting from all the children, serum separated and the samples were stored at  $-20^{\circ}\text{C}$  until analysis. Lipid profile which includes total cholesterol (TC), low density lipoprotein-cholesterol (LDL-C), high density lipoprotein-cholesterol

(HDL-C) were analyzed by enzymatic methods using autoanalyser (Randox Daytona). Serum triglycerides (TG) by GPO-PAP method using autoanalyser (Randox Daytona), fasting glucose levels were analyzed by glucose oxidase method using autoanalyser (Randox Daytona). Serum insulin, serum C-peptide were measured using ELISA (Monobind Inc USA), serum leptin was measured by ELISA kit (Diagnostic Biochem Canada Inc). Urinary glucose and ketone bodies were measured by commercial strip method (Standard Diagnostics Inc., Korea). Insulin resistance index (IRI), homeostasis model assessment (HOMA-IR) calculated by following formula:

$$\text{IRI} = \frac{\text{fasting glucose}(\text{mg/dl})}{\times \text{fasting insulin}(\mu\text{U/ml})/450},$$

$$\text{HOMA-IR} = \frac{\text{fasting insulin } (\mu\text{U/ml})}{\times \text{fasting glucose } (\text{mmol/l})/22.5}.$$

## Statistical Analysis

Statistical analysis of the data was done by using SPSS Package 9.0. Results expressed as Mean  $\pm$  SD. *P* value  $<0.005$  were considered to be statistically significant. Data of significance among the groups was analyzed by one way ANOVA and Bonferroni comparison. Some of the parameters are slightly skewed, so we have applied logarithmic transformations for all statistical analysis. Correlation analysis was done by Pearson correlation coefficient at 5% level of significance.

## Results

We studied 185 subjects (59 control, 52 obese, 49 overweight, 25 congenital heart diseased children and adolescents). 110 were boys and 75 were girls with the age range of 10–17 years. We excluded 78 subjects who refused the study protocol (or) had incomplete data (or) previously diagnosed with various disorders. The biochemical and anthropometric characteristics of study subjects are shown in Table 1. The anthropometric measurements were found to be significantly higher in obese and overweight children and adolescents than in control children and adolescents. Serum insulin levels were significantly higher in obese ( $19.68 \pm 8.75 \mu\text{U/ml}$ ), overweight ( $15.27 \pm 6.82 \mu\text{U/ml}$ ), congenital heart disease ( $5.65 \pm 2.35 \mu\text{U/ml}$ ) ( $P < 0.001$ ) than in control children ( $4.04 \pm 3.25 \mu\text{U/ml}$ ). Serum leptin, serum C-peptide, IRI, HOMA-IR were found to be significantly elevated in overweight and obese children ( $P < 0.001$ ) than controls. However, children with congenital heart disease showed significantly elevated serum insulin, ( $P < 0.001$ ), decreased serum leptin levels ( $<0.005$ ). In addition, serum C-peptide, HOMA-IR levels

**Table 1** Comparison between controls and overweight, obese, congenital heart disease children

	Control (N = 59)	Overweight (N = 52)	Obese (N = 49)	Congenital heart disease (N = 25)
Age (years)	14.54 ± 1.12	14.14 ± 1.34	14–17 ± 1.40	12.76 ± 2.26
BMI ( $\text{kg}/\text{m}^2$ )	17.97 ± 2.57	24.51 ± 1.34**	28.77 ± 3.06**	15.72 ± 3.21*
WHR	0.88 ± 0.10	1.00 ± 0.13**	1.03 ± 0.14**	0.90 ± 0.04 <sup>NS</sup>
Systolic B.P. (mmHg)	116.78 ± 6.00	120.41 ± 6.76 <sup>NS</sup>	124.04 ± 8.91**	110.52 ± 9.46*
Diastolic B.P. (mmHg)	73.39 ± 6.85	75.71 ± 8.42 <sup>NS</sup>	75.19 ± 8.96 <sup>NS</sup>	65.08 ± 8.58**
Insulin ( $\mu\text{U}/\text{ml}$ )	4.04 ± 3.25	15.27 ± 6.82**	19.68 ± 8.75**	5.65 ± 2.35**
IRI	0.77 ± 0.63	2.81 ± 1.31**	3.52 ± 1.61**	1.16 ± 0.58**
HOMA-IR	0.86 ± 0.69	3.12 ± 1.47**	3.93 ± 1.78**	1.28 ± 0.64 <sup>NS</sup>
C-peptide (ng/ml)	1.67 ± 0.89	2.82 ± 1.05**	3.75 ± 1.42**	2.29 ± 1.12 <sup>NS</sup>
Leptin (ng/ml)	7.97 ± 2.79	20.64 ± 11.18**	36.88 ± 18.60**	6.20 ± 4.23*
TC (mg/dl)	136.64 ± 18.32	150.06 ± 19.83 <sup>††</sup>	155.10 ± 21.65**	144.12 ± 29.13 <sup>NS</sup>
TG (mg/dl)	72.73 ± 29.14	92.59 ± 39.60 <sup>NS</sup>	105.96 ± 44.32**	108.48 ± 53.26**
LDL-C (mg/dl)	87.19 ± 13.69	90.67 ± 13.43 <sup>NS</sup>	93.63 ± 14.28 <sup>NS</sup>	79.64 ± 21.88 <sup>NS</sup>
HDL-C (mg/dl)	37.63 ± 3.99	38.76 ± 4.76 <sup>NS</sup>	38 ± 4.01 <sup>NS</sup>	40.64 ± 5.93 <sup>†</sup>
Fasting glucose (mg/dl)	86.51 ± 6.86	81.43 ± 5.33*	80.52 ± 6.00**	91.32 ± 14.67 <sup>NS</sup>
Food habit (non-veg %)	69.4	77.5	82.6	92

Results are expressed in mean ± SD; \*\*  $P < 0.001$ ; \*  $P < 0.005$ ; ††  $P < 0.01$ ; †  $P < 0.05$

NS Non significant, BMI body mass index, WHR waist to hip ratio, IRI insulin resistance index, HOMAIR homeostasis model assessment, TC total cholesterol, TG triglycerides

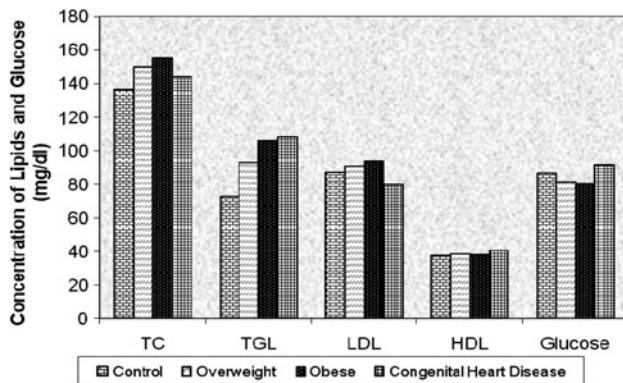
were non-significant when compared to controls. Lipid profile, fasting serum glucose levels between different groups are shown in Fig. 1.

Girls had higher BMI and serum insulin levels in all the groups than the boys. The biochemical and anthropometric differences between boys and girls are shown in Table 2. The relationship between serum insulin, biochemical and anthropometric parameters for all the subjects and for boys and girls are shown in Table 3. The serum insulin levels are significantly in positive correlation with BMI, WHR, systolic blood pressure and diastolic blood pressure, serum

C-peptide, serum leptin, total cholesterol, triglycerides, LDL-cholesterol, whereas serum insulin levels are negatively correlated with fasting glucose levels in all the groups ( $P < 0.003$ ) and HDL-cholesterol levels were found to be non-significant among all the groups. None of them had shown positive test for urinary glucose and urinary ketone bodies.

Figure 2 shows correlation of serum insulin and BMI, serum C-peptide, serum leptin values for obese boys. Correlation of serum insulin and BMI, serum C-peptide, serum leptin values for obese girls are described in Fig. 3.

Family history of obesity was found to be 60% among overweight and obese children and adolescents. However, only around 20% of family history of obesity was seen in both control and congenital heart diseased children and adolescents. Family history of type 2 diabetes mellitus was found in 38.7% overweight, 28.8% in obese, 24% in congenital heart disease, whereas only 10.1% in control children. Obese, overweight, congenital heart disease children had family history of 34.7, 38.5 and 24% hypertension, respectively, when compared to 13.6% in control children. Family history of heart disease was found in 10.2% in overweight, 8% in congenital heart disease and 5.8% in obese children when compared to 3.4% in control children. Socio-economic status and physical training programme of all children enrolled for the study were found to be almost similar.



**Fig. 1** Mean lipid profile, fasting serum glucose levels between different groups. TC total cholesterol, TG triglycerides, LDL low density lipoprotein cholesterol, HDL high density lipoprotein cholesterol

**Table 2** Comparison between boys and girls of different groups

	Control		Overweight		Obese		Congenital heart disease	
	Boys (N = 34)	Girls (N = 25)	Boys (N = 30)	Girls (N = 19)	Boys (N = 34)	Girls (N = 18)	Boys (N = 12)	Girls (N = 13)
BMI (kg/m <sup>2</sup> )	17.8 ± 2.6	18.1 ± 2.5	24.2 ± 1.4**	25 ± 1.1**	28.6 ± 3.0**	29 ± 3.2**	15.3 ± 2.6 <sup>†</sup>	16 ± 3.7 <sup>NS</sup>
WHR	0.89 ± 0.08	0.87 ± 0.12	0.96 ± 0.06*	1.06 ± 0.18**	1.01 ± 0.10**	1.07 ± 0.18**	0.90 ± 0.03 <sup>NS</sup>	0.90 ± 0.05 <sup>NS</sup>
SBP (mmHg)	115.5 ± 6.1	118.4 ± 5.5	121.3 ± 6.2 <sup>††</sup>	118 ± 7.3 <sup>NS</sup>	123.5 ± 9.1**	125 ± 8.5 <sup>†</sup>	108.6 ± 9.4 <sup>†</sup>	112.2 ± 9.4 <sup>NS</sup>
DBP (mmHg)	71.1 ± 7.2	76.4 ± 4.9	75.3 ± 9.3 <sup>NS</sup>	76.3 ± 6.8 <sup>NS</sup>	72 ± 7.7 <sup>NS</sup>	81.1 ± 8.3 <sup>NS</sup>	64.3 ± 4.5 <sup>NS</sup>	65.7 ± 11.2**
Insulin (μU/ml)	3.18 ± 2.92	5.2 ± 3.37	14.88 ± 7.21**	15.9 ± 6.29**	18.1 ± 8.09**	22.65 ± 9.41**	5.66 ± 2.96**	5.65 ± 1.74 <sup>NS</sup>
IRI	0.60 ± 0.55	1.01 ± 0.65	2.74 ± 1.43**	2.91 ± 1.13**	3.22 ± 1.44**	4.09 ± 1.81**	1.14 ± 0.63**	1.17 ± 0.55 <sup>NS</sup>
HOMA-IR	0.67 ± 0.61	1.12 ± 0.72	3.04 ± 1.59**	3.24 ± 1.28**	3.75 ± 1.59**	4.6 ± 1.97**	1.26 ± 0.69	1.3 ± 0.61 <sup>NS</sup>
C-peptide (ng/ml)	1.41 ± 0.76	2.04 ± 0.94	2.94 ± 1.13**	2.63 ± 0.91 <sup>NS</sup>	3.47 ± 1.34**	4.28 ± 1.45**	2.43 ± 1.21 <sup>†</sup>	2.15 ± 1.05 <sup>NS</sup>
Leptin (ng/ml)	7.72 ± 2.81	8.31 ± 2.78	17.74 ± 11.12**	25.2 ± 9.92**	29.25 ± 14.4**	51.3 ± 17.2**	5.55 ± 4.0 <sup>††</sup>	6.8 ± 4.43 <sup>NS</sup>
TC (mg/dl)	134.9 ± 20	138.9 ± 14	149.8 ± 16 <sup>††</sup>	150.3 ± 24 <sup>NS</sup>	150.7 ± 18 <sup>††</sup>	163.3 ± 24 <sup>††</sup>	137.5 ± 21 <sup>NS</sup>	150.1 ± 34 <sup>NS</sup>
TG (mg/dl)	77.2 ± 33.8	66.5 ± 20.2	89.8 ± 37 <sup>NS</sup>	96.9 ± 43.9 <sup>NS</sup>	101.5 ± 38.7 <sup>NS</sup>	114.2 ± 53.4*	111.7 ± 53 <sup>†</sup>	105.4 ± 54 <sup>†</sup>
LDL-C (mg/dl)	85.1 ± 15.6	89.9 ± 10.1	90.2 ± 13.5 <sup>NS</sup>	91.4 ± 13.6 <sup>NS</sup>	91.9 ± 13.7 <sup>NS</sup>	96.7 ± 15.2 <sup>NS</sup>	77.3 ± 11.5 <sup>NS</sup>	81.7 ± 28.7 <sup>NS</sup>
HDL-C (mg/dl)	37.8 ± 4.1	37.2 ± 3.8	39.8 ± 5.3 <sup>NS</sup>	37.1 ± 3.2 <sup>NS</sup>	37.9 ± 3.9 <sup>NS</sup>	38.1 ± 4.3 <sup>NS</sup>	40.6 ± 5.2 <sup>NS</sup>	40.6 ± 6.7 <sup>NS</sup>
Fasting glucose (mg/dl)	85.8 ± 6.9	87.4 ± 6.7	80.8 ± 6.0 <sup>†</sup>	82.4 ± 3.9 <sup>NS</sup>	79.8 ± 5.7 <sup>††</sup>	81.8 ± 6.4 <sup>NS</sup>	91.2 ± 14.1 <sup>NS</sup>	91.3 ± 15.6 <sup>NS</sup>

Results are expressed in mean ± SD; \*\* P < 0.001; \* P < 0.005; † P < 0.01; †† P < 0.05

NS non-significant, BMI body mass index, WHR waist to hip ratio, IRI insulin resistance index, HOMAIR homeostasis model assessment, TC total cholesterol, TG triglycerides

## Discussion

The prevalence of metabolic syndrome is increasing rapidly in both obese and overweight children. It is estimated that there is each half unit increase in BMI associated with a 50% increase risk of insulin resistance syndrome among overweight children and adolescents [12, 13]. The goal of this study was to evaluate the risk of insulin resistance in South Indian children and adolescents and to elucidate the relationship between serum insulin and other biochemical, anthropometric parameters in obese, overweight and congenital heart disease children.

The present study demonstrates elevated levels of serum insulin in both obese and overweight children. The data suggest that childhood obesity and overweight often precedes the hyperinsulinemic state and fasting insulin levels determine insulin resistance [7, 12]. Data reported in the present study shows an elevated insulin resistance index (IRI), homeostasis model assessment (HOMA-IR) in both obese and overweight children. Measurement of HOMA-IR had high sensitivity and specificity among children and adolescents for measuring insulin resistance and it is more reliable than FGIR and QUICKI and our study is in agreement with earlier studies [13, 14]. We observed significantly elevated BMI, WHR in both obese and overweight children and adolescents than controls and our observations strongly suggest the association between adiposity and insulin resistance [15, 16]. Serum C-peptide, serum leptin levels found to be significantly elevated in obese, overweight children and adolescents than controls. Many studies have reported higher leptin levels

shown to predict the development of metabolic syndrome independently of baseline obesity [17]. The results of our study show positive correlation between serum insulin and BMI, WHR, serum C-peptide, serum leptin and our findings agree with those reported by others [12, 18, 19].

Children with congenital heart disease had significantly higher levels of serum insulin, and decreased levels of BMI, serum leptin on comparison with controls. However, WHR, HOMA-IR, serum C-peptide levels were found to be non-significant when compared to controls. This may be due to increase of catecholamine in circulation [20].

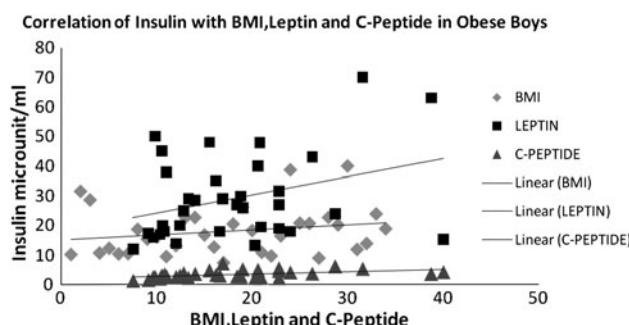
On further comparison between boys and girls, in all the groups, we found higher levels of BMI, WHR, serum leptin, IRI, HOMA-IR, serum insulin in girls than boys and it is well known that change of sex hormones may be responsible for gender differences [21, 22].

In our study, systolic blood pressure was found to be increased in obese children and adolescents, whereas non-significant in overweight children on comparison with controls. Children with congenital heart disease showed significantly decreased systolic blood pressure than control children. Diastolic blood pressure levels were found to be non significant among overweight, obese children than controls. However, diastolic blood pressure levels were decreased in children with congenital heart disease than controls. Our observations strongly suggest that insulin resistance has been associated with only borderline hypertension, independent of body mass index in children and adolescents and the present study is in agreement with previous findings [23].

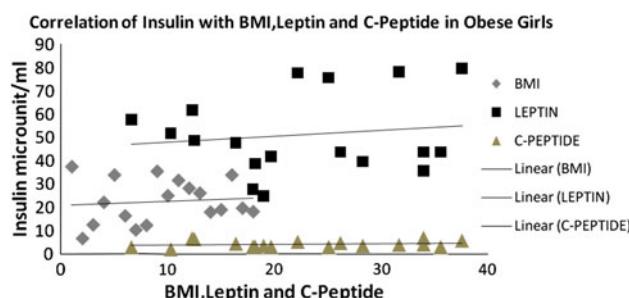
**Table 3** Pearson correlation analysis between Serum insulin and anthropometric, biochemical variables of the study subjects

BMI body mass index, WHR waist to hip ratio, IRI insulin resistance index, HOMAIR homeostasis model assessment, TC total cholesterol, TG triglycerides

	Overall (185) r	P value	Boys (110) r	P value	Girls (75) r	P value
BMI ( $\text{kg}/\text{m}^2$ )	0.74	0.001	0.72	0.001	0.80	0.001
WHR	0.54	0.001	0.52	0.001	0.63	0.001
Systolic B.P. (mmHg)	0.31	0.001	0.31	0.001	0.30	0.008
Diastolic B.P. (mmHg)	0.24	0.001	0.22	0.023	0.24	0.037
C-peptide (ng/ml)	0.62	0.001	0.64	0.001	0.60	0.001
Leptin (ng/ml)	0.63	0.001	0.63	0.001	0.68	0.001
TC (mg/dl)	0.37	0.001	0.36	0.001	0.40	0.001
TG (mg/dl)	0.25	0.001	0.22	0.023	0.30	0.008
LDL-C (mg/dl)	0.27	0.001	0.25	0.008	0.29	0.011
HDL-C (mg/dl)	0.05	0.49	0.06	0.509	0.05	0.688
Glucose (mg/dl)	-0.22	0.002	-0.26	0.005	-0.19	0.105
IRI	0.99	0.001	1.00	0.001	0.99	0.001
HOMA-IR	0.90	0.001	0.90	0.001	0.91	0.001



**Fig. 2** Correlation of serum insulin and BMI, serum C-peptide, serum leptin values in obese boys



**Fig. 3** Correlation of serum insulin and BMI, serum C-peptide, serum leptin values in obese girls

It has been consistently observed that elevated total cholesterol, triglycerides, LDL-cholesterol levels in overweight and obese children than control children, and its positive correlation with serum insulin levels and our findings supports the studies reported previously [3]. Elevated LDL-cholesterol levels in obese and overweight children were observed, but they were found to be non-significant. In addition, HDL-cholesterol levels were found to be non-significant among overweight and obese children and our findings are in alignment with earlier studies [24].

In the present work, we observed significantly elevated levels of triglycerides and HDL-cholesterol. However, total cholesterol and LDL-cholesterol levels were found to be non-significant in congenital heart disease children. This is possibly due to excessive intake of macronutrients.

The main finding in the present study was fasting glucose levels were significantly decreased in overweight and obese children, negatively correlated with serum insulin levels. Probably insulin decreases blood glucose concentrations by reducing hepatic gluconeogenesis and glycogenolysis and by enhancing glucose uptake into striated muscles and adipocytes [13]. Previous studies have produced mixed results concerning fasting glucose levels in obese children [14, 24]. These findings suggest insulin resistance constitutes an important risk factor for cardiovascular diseases even in the absence of hyperglycemia or diabetes and it is commonly associated with obesity [13, 25].

Another finding of the present study was, we identified nine children (five girls, four boys) and adolescents with features of metabolic syndrome according to International Diabetes Federation Criteria [26], which were not identified in them earlier and the clinical reports were distributed to the school authorities. Most of them showed  $\text{BMI} > 30$  with higher triglycerides ( $>150 \text{ mg/dl}$ ), lower HDL-cholesterol ( $<40 \text{ mg/dl}$  for females,  $<50 \text{ mg/dl}$  for males) levels. In addition, we identified 40 obese, 29 overweight, 1 congenital heart disease children and adolescents with the risk of insulin resistance according to IDF cutoff values for insulin resistance (insulin  $> 10 \mu\text{U}/\text{ml}$  and HOMA  $> 2.38$ ). There is no universal definition of metabolic syndrome for children and adolescents. So, we followed IDF criteria for the assessment of metabolic syndrome and insulin resistance. It has been consistently observed that family history plays an important role in insulin resistance syndrome [27, 28] about 70% children with insulin resistance had family history of obesity, diabetes mellitus and hypertension. The potential

limitation of our study was lack of puberty assessment in children and euglycemic hyperinsulinemic clamp for evaluating insulin resistance, measurement of in detail dietary habits of children. Insulin resistance was made based on single test of fasting insulin and fasting glucose.

In conclusion, data confirm consistent positive correlation between serum insulin and anthropometric, clinical and biochemical parameters in all the groups. We observed negative correlation between serum insulin and fasting glucose levels, HDL-cholesterol levels were found to be non-significant among all the groups. Our findings strongly suggest that the risk of insulin resistance was higher in obese and overweight individuals (69%) than control and congenital heart disease individuals. In the present study, we found insulin resistance was strongly associated with metabolic syndrome and its components especially central obesity and hypertriglyceridemia. The data suggest that obesity may be instrumental in bringing out symptoms of various metabolic disorders. Further studies are being planned on larger sample size to draw a healthy conclusion for clinical management of the patients.

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